EUROSTRATAFORM: Sediment Transport Processes and Shelf Development

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LONG-TERM GOAL

The long-term goal of the sediment transport and accumulation component of Euro-STRATAFORM is to link sediment transport processes to the formation and preservation of event beds in sediment deposits.

OBJECTIVES

Our main objective within EuroSTRATAFORM is to investigate sediment dispersal mechanisms at shelf water depths. Instrumentation of the shelf on the Po River delta and in the Apennine Rivers region of the Adriatic Sea, seasonal water-column profiling and subsequent data analyses have allowed us to begin to:

1. investigate the range of processes responsible for shelf transport of sediment (including "storm-driven" and "density-driven" processes), their dominant pathways (surface plume, intermediate nepheloid layer, or bottom boundary layer), their relationship to grain size and their role in shelf development,

2. provide a regional climatology of sediment transport processes (Po River delta & Apennine Rivers regions),

3. contrast results in the Adriatic Sea (from two study areas: one with concurrent oceanic forcing and river discharge, and one with disconnected oceanic forcing and river discharge in time) with results from STRATAFORM (the Eel River shelf).

APPROACH

Two study areas within the Adriatic Sea were chosen to be investigated as part of EuroSTRATAFORM which provide contrasts to the Eel River shelf, and allow evaluation of two different end-member river systems discharging into a relatively low-energy oceanic basin. The two study areas are the *Po System* and the *Apennine System*. Discharge from the Po River comes from a large drainage basin and is relatively disconnected in time from energetic conditions in the Adriatic. The sediment deposit located mainly to the south of the Po River mouth suggests dominantly alongshelf dispersal of sediment from this point source. In contrast, discharge from the Apennine

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rivers is highly episodic, coming from a distributed-source system of small, high-yield drainage basins. High discharge and more energetic oceanic conditions probably occur concurrently. The shelf is characterized by steep slopes and a prograding clinoform feature which suggests that sediment discharged from the rivers is likely transported rapidly across-shelf. Similarly, the Eel River is also an episodic, high-yield system and floods occur contemporaneously with high-energy conditions in the ocean basin. However, the dominant depositional feature is a mid-shelf mud deposit rather than a clinoform.

The EuroSTRATAFORM project was initiated following a 100-year flood event of the Po River in October 2000 which resulted in a thick, greater than 15cm, sediment deposit on the subaqueous delta in close proximity to the main Po distributaries. The processes that contribute to and redistribute sediment were subsequently investigated by deploying an instrumented benthic tripod on the 12-m isobath, from January 2001 to April 2002, which collected time-series data of nearbed sediment transport parameters. An additional series of deployments occurred from October 2002 until May 2003, providing a third winter of time-series data. In addition, a second instrumented system was deployed offshore of the Pescara River mouth on the Apennine coastline in the winter of 2002/2003. Between the experiments on the Po and Apennine systems, three winter periods and one summer of time-series data near the Po and one winter of data near Pescara have been collected. From these data a regional climatology of sediment transport events can be developed that allows comparison to other systems.

Spatial variations in processes are being evaluated utilizing water-column profiling efforts collecting salinity, temperature, and suspended-sediment concentrations during nine seasonal cruises between December 2000 and May 2003. The water-column profiling performed by the UW occurred not only in the instrumented focus areas at deployment/retrieval times, but was also coordinated with the regional coring performed by the seabed group to obtain a study of the combined Po/Apennine systems and to examine the differences between a point-source (Po) and distributed-source (Apennine) system, and the intermingling of the two systems.

Our work is not only directed at a few specific scientific questions, but the longer-term (3-yr) and extensive along-shelf observations provide a regional context in which others can frame their results. We have and plan to continue to collaborate with and to supply input to the seabed, modeling and plume/coastal current efforts.

WORK COMPLETED

Po System: Since this project started in December 2000 (with pre-project funding in response to the October 2000 flood in the Po River), we have maintained a boundary-layer tripod near the mouth of the Po for a total period of 18 months over three winter periods (Jan 2001 – Apr 2002, Nov 2002-Feb 2003). This provides over a year of continuous data and an additional winter (high discharge period of the Po River) in three consecutive years. The tripod collected data to examine boundary-layer processes, sediment characteristics, and water-column currents. Analysis of this high-quality data set is in process and initial results have been published (Fox et al, submitted; Pullen et al., in press). During the final deployment of the instruments, bottom trawlers apparently removed the instrument, thus there is no data on the Po River subaqueous delta for the final period (Feb 2003 - May 2003).

Apennine System: An instrumented tripod (similar to the one deployed on the Po System) was deployed in the region of the Pescara River, as part of an overall array of boundary-layer tripods (WHOI/USGS/Dalhousie/UW/ICM). The array was designed to examine the sediment dispersal

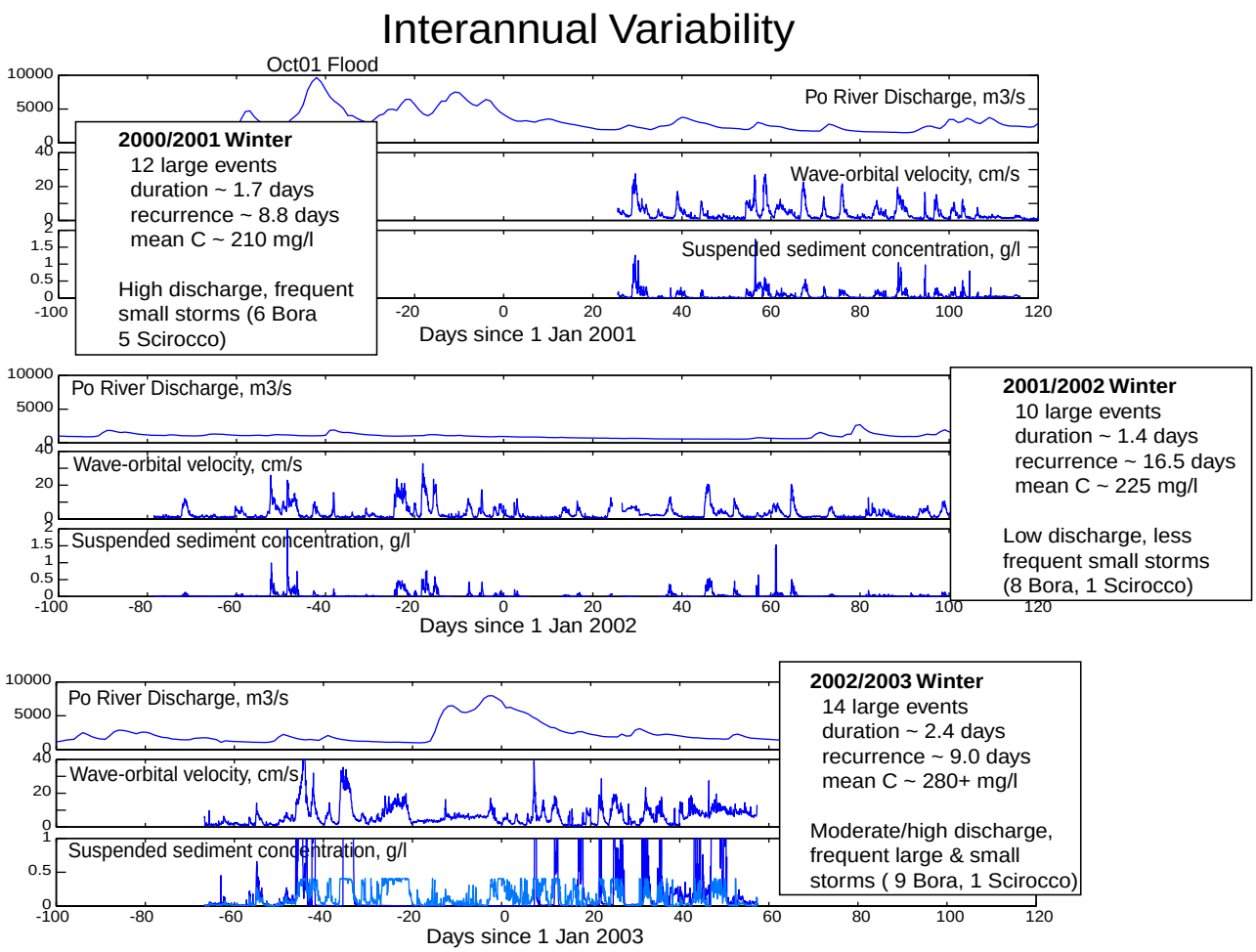

Figure 1. Three winter periods of data collected on the Po River delta. The top three panels show river flow, wave-orbital velocity, and resulting suspended-sediment concentration for the winter of 2000/2001. The middle three panels show the same data for 2001/2002, and the bottom three panels show the period in 2002/2003 (note the suspended-sediment sensors are at different elevations from the seabed in this period).

dynamics from the mouth of the Po to south of Pescara. Our instrument deployments were also coordinated with studies of processes on the topset and foreset regions of the clinoform feature characteristic of this area (with Puig, ICM). The data is also being analyzed for studies of internal-wave dynamics in the crenulated region of the foreset (Puig, ICM and Cacchione).

Water-Column Profiling: During instrument deployment and turnaround times, we have conducted detailed water-column profiling near the Po mouth (9 seasonally varying cruises). Continued profiling of the water column (CTD/suspended-sediment concentration and pumped samples) during instrument deployment/retrieval times at the time-series seabed coring sites provides information on spatial variability of sediment suspension and provide collaborative opportunities with investigations of seabed processes (Nittrouer, UW and Wheatcroft, OSU), flocculation dynamics (Hill, DAL, and Milligan, BIO) and flume studies of convective sedimentation (Parsons, UW). Interaction with A.

Boldrin (CNR, Venice) provides biological significance to the proposed work (Boldrin et al., 2001). In the last year, we performed three large-scale surveys of water-column properties from the mouth of the Po to the southern edge of the Apennine region. Although our data is not synoptic, we can provide more detailed evaluations of water-column properties at specific sites which adds to the large-scale water column surveys performed by WHOI/BC.

RESULTS

Analysis of sediment transport events is underway for the long, monitoring time series on the Po River delta, as well as off the Pescara River mouth. Strong interannual variability is being observed in the three winter data sets on the Po River delta (Fig. 1). Although the length of winter data varies, and thus the absolute numbers of events is not a good measure, the river discharge, duration and origin of wave-orbital velocity varies significantly in the three periods. This emphasizes the need for long-term data collection to evaluate all of the transport mechanisms to determine their effect on strata formation.

The dispersal of sediment away from the Po River mouth can be largely attributed to both surface plume and bottom boundary layer (BBL) processes. In environments with larger mean waves and currents, such as on the northern California and Amazon continental shelves, the BBL sediment load is almost always larger than the surface plume load over the depositional site. A majority of the Po sediment falls out of the water column in the form of flocs inshore of the 6-m isobath, but there is still sediment carried in the surface plume offshore of the 6-m isobath. During relatively calm conditions, sediment load in the Po River surface plume over the delta has been observed to be up to 5 times larger than that in the BBL along the 10- and 15-m isobaths. During calm conditions, the surface plume load exceeds that in the BBL. Yet during storms, which occur about 10% of the time along the western Adriatic continental shelf, the BBL sediment load greatly exceeds the surface plume load and the along-isobath currents may be enhanced, providing an opportunity for a considerable amount of resuspended sediment to be advected in the BBL.

In the BBL, Bora-wind resuspension events were found to make the dominant contribution to the net sediment flux, while Scirocco wind events were found to be of lesser magnitude and more ambiguous direction. The wind events add to nearbed shear stress and BBL transport, as well as increase surface plume velocities. Near the Po Delta the cumulative flux appears to be somewhat spatially variable due to interaction between the thermohaline and wind-driven currents and the morphology of the delta. But in general, the net flux is towards the south, and there is limited across-shore flux. The sediment-transport dynamics are reflected in the distribution of flood sediment on the Po River delta, with most of the sediment being initially deposited in relatively close proximity to the river mouth from the surface plume and a fraction of this being subsequently resuspended in the BBL during storm events and transported southwards in the prevailing currents.

Bora wind resuspension events dominate the alongshore transport climatology not only near the Po River delta, but also in the Pescara River mouth region. Observed resuspension events at the Pescara River mouth had significantly less magnitude than those at the Po River delta. The cumulative flux near the Pescara River is almost completely southward along bathymetry with little across-margin transport at the 12-m depth. The coastal current, when enhanced by strong Bora wind events, adds significantly to the boundary layer shear stress and contributes to the advection of greater suspended sediment concentrations. During the initial 15-month Po deployment observed sediment resuspension events at the Po River mouth due to Bora events reached a maximum of 2 g/l at 12cmab, and due to Scirocco events reached 1 g/l. At the Pescara River mouth Bora events caused less sediment

resuspension, 1.5 g/l at 13 cmab, although similar magnitude shear stresses occurred, suggesting differences in seabed composition and consolidation.

IMPACT/APPLICATION

The work described will allow the sediment transport community not only to extend results from the STRATAFORM project, but also to gain new insights on transport processes in a relatively low wave energy environment. Studies near the mouth of the Po River allow investigation of transport processes where floods and storms are not necessarily concurrent in contrast to those of the Eel River shelf. The two study areas within the Adriatic provide a comparison between transport processes away from the mouth of a point source (Po Region) and at the downstream end of a multiple source system (Apennine Region). The long-term time series evauation of interannual variability is important to the overall study as it provides context for the shorter-term experiments.

TRANSITIONS

The EuroSTRATAFORM program is a collaborative project among many investigators. Understanding of the sediment dispersal mechanisms in these systems is important to the overall success of this project, if we are to attain the long-term goal of linking modern transport processes to formation and preservation of strata. The data collected is being used by multiple investigators in the EuroSTRATAFORM program. Specifically, Pullen (NRL) and Harris (VIMS) are using time-series data to validate their physical oceanographic and sediment transport models. Sediment size and settling velocity data from the time-series location is being used by Hill (Dalhousie).

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